New Initiatives: The Accelerator Physics Group and the Next Generation of Light Sources

Reported by Alan Jackson

During 1997 the Accelerator Physics Group began discussions with the ALS user community as to what parameters should define a next-generation light source. Since free-electron laser systems are being pursued at the three other DOE light source facilities [(Stanford Synchrotron Radiation Laboratory (SSRL), Advanced Photon Source (APS), and National Synchrotron Light Source (NSLS)], we chose to follow different alternatives. Two areas of opportunity came out of these discussions. The first was to push the beam sizes and emittances even smaller in a ring based system.

The drivers for this type of facility are: (1) potential for many users, particularly on high brightness bend-magnet beamlines; (2) small-gap, short period insertion devices to get to high photon energies at relatively low ($\approx$ 2 GeV) electron-beam energy; and (3) enhanced performance for users of transverse coherence, particularly at higher photon energies. The results of the accelerator physics study are presented below. However, when these capabilities were discussed further with the user community, we discovered that the market for such a machine was not yet developed—clearly the community is still learning how to deal with the beam brightnesses presented by the third-generation machines.

This chicken-and-egg situation can also be used to describe the second area that we pursued—generation of femtosecond pulses of x rays. However, in this case we found more immediate interest. Users are already performing proof-of-principle experiments on the ALS, at very low photon fluxes, and are desperate for more photon intensity. Our initial discussions with local users led to an informal workshop attended by users from outside Berkeley Lab, and by accelerator physicists from Berkeley Lab's Center for Beam Physics, Stanford Linear Accelerator Center (SLAC), and Lawrence Livermore National Laboratory (LLNL). A discussion of the workshop findings is given below.

ALS-N

ALS-N is conceived as an ultrahigh-brightness source of synchrotron radiation (natural emittance $\approx$ 0.5 nm·rad) at an energy of 2 GeV to 2.5 GeV, with a circumference in the range of 350 to 400 m so that it could fit on a site at Berkeley Lab. The main issues associated with such a facility are lattice design and dynamic aperture, the influence on the emittances of intrabeam scattering, and Touschek lifetime. Other considerations are beam stability and cost. To address this last issue, we borrowed an idea from the Fermilab recycler ring, which is to use permanent magnets for most of the magnet lattice. With the small aperture anticipated for the ring, around 20 mm (horizontal) $\times$ 10 mm (vertical), such magnets could be relatively small and inexpensive. Further, the magnets would be light in weight and have inexpensive support systems. Another advantage is that the magnets have no power requirements, and therefore do not require cooling water, further reducing cost and also sources of vibration and temperature variation.

A sample lattice was developed based on the concept of compact minimum-theoretical-emittance lattice cells, matched into long straight sections for insertion devices. The layout (on the site of the Bevatron) and a list of parameters are given in Figure 2-15 and Table 2-4, respectively. This lattice was used to investigate the issues described above. Dynamic aperture is indeed an issue, and a satisfactory sextupole distribution has not yet been worked out. Both the electron-beam emittance and the bunch length suffer from intrabeam scattering. Even so, significant improvements in beam brightness could be achieved over those available at the ALS, as shown in Figure 2-16. Assuming 1% coupling and use of a third-harmonic rf system (to increase the bunch length), the Touschek lifetime was estimated at more than 4 hours.

More information on this work is reported in LBNL-39799 (A. Jackson et al., "ALS-N - A Candidate for a Next-Generation Light Source") or in the proceedings of the 1997 Particle Accelerator Conference.

Figure 2-15. Footprint of the ALS-N on the Bevatron site. The straight-section beamlines are 40 m long.

Table 2-4. Parameters of ALS-N.

Energy	2 GeV
Circumference	380 m
Natural emittance	5.5×10^{-10} mrad
Natural energy spread	8×10^{-4}
Momentum compaction	6.7×10^{-4}
Tunes x, y	33.18, 23.73
Chromaticities x, y	–46, –76
Free straight	16, each 5 m long
β_x, β_y in straight	3 m, 3.2 m
β_x, β_y in arc bend	0.8 m, 4 m
Maximum current	400 mA

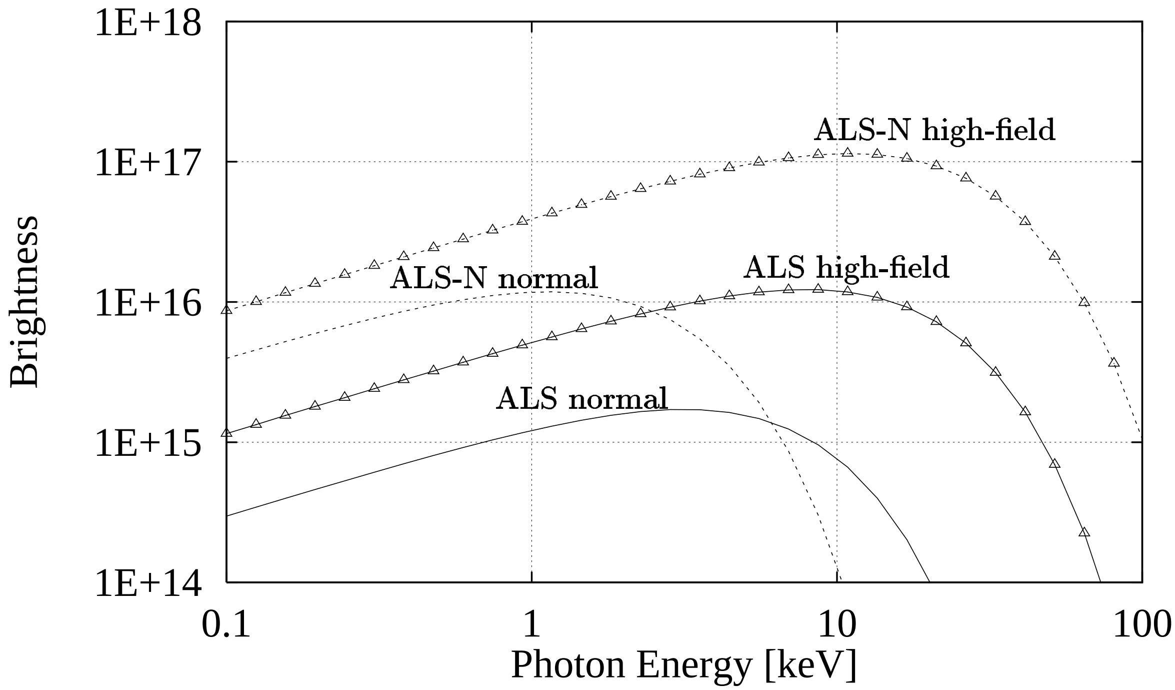

Figure 2-16a. Brightness [photons/(s mm^2 mrad^2 0.1%b.w.)] from normal (1.2 T) and high-field (5 T) dipoles at the present ALS and the ALS-N.

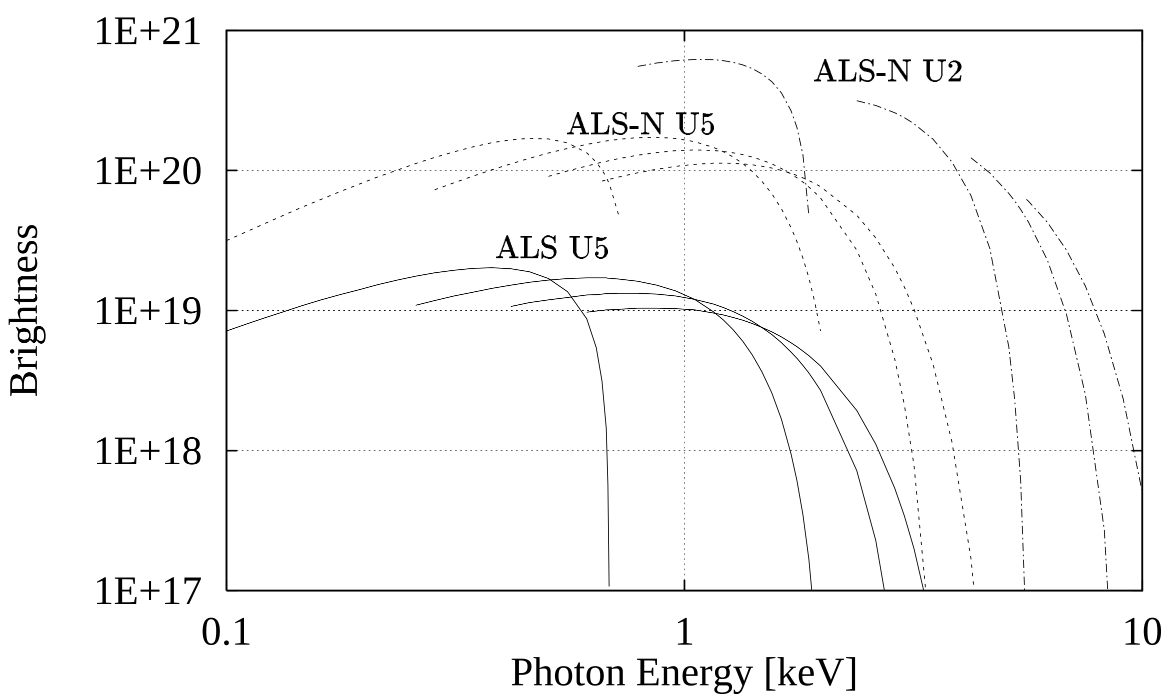

Figure 2-16b. Brightness [photons/(s mm^2 mrad^2 0.1%b.w.)] from insertion devices (U5 = 5 cm undulator period, U2 = 2 cm undulator period) at the present ALS and the ALS-N.

Workshop on the Uses and Generation of Femtosecond Radiation

The goal of the workshop, held at Berkeley Lab in February 1998, was to develop a set of parameters that would be useful for specific experiments and to describe to the user community the different techniques that might eventually be used to meet their requirements. The workshop was indeed informative and very useful. Certainly, the cross-discipline interactions were very successful. However, it became clear during the discussion period that the experimenters present had not thought much beyond the extremely demanding experiments that they are doing right now, and we did not come away from the workshop with the hoped-for set of parameters that could be the basis for a new source. The workshop did however spur a number of investigators to think further about what they would need to push forward with their experiments; the types of experiments and the parameters required are:

- Order-disorder transitions in ordered solids, e.g., silicon melting (using Bragg diffraction).
- Order-disorder transitions in amorphous materials, e.g., the molten carbon insulator-metal transition (using EXAFS).
- Chemical dynamics at surfaces or in solution, e.g., in laser desorption of CO from metal surfaces (using EXAFS).
- Protein-chromophore dynamics, e.g., bacteriorhodopsin isomerization (using diffraction).

The photon parameters required for these experiments are typically:

- Energy: 1–20 keV.
- Bandwidth: 10^{-3}.
- Pulse width: <100 fs.
- Flux: $>10^4$ photons/pulse.
- Repetition rate: ~100 kHz.
- Sample size: 100 μm.
- Angle subtended: <1 mrad.
- Synchronization: to within 100 fs.

Some novel source concepts also evolved during and immediately after the workshop, involving both linac- and ring-based systems. These will be pursued in the coming year.